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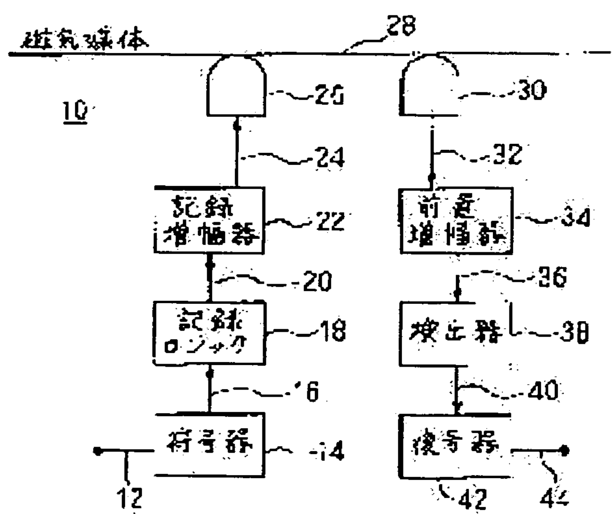
(54) TERNARY CODE MAGNETIC RECORDING SYSTEM

(57)Abstract:
PROBLEM TO BE SOLVED: To provide an information encoding method, a decoding method, and a digital information storage device which make it possible to store as much information as possible even when the same head and the same medium are used since the capacity of digital information storage increases.
SOLUTION: A magnetic storage system 10 decode a binary input signal 12 into a ternary code 16 of a code rate 1, and a recording logic part 18 converts the ternary code into three states of 1, 0, and AC, which are recorded on a medium 28 by a conventional recording head on a saturation basis. A signal 32 read out by a conventional reproducing head 30 is amplified, and then detected as a digital ternary signal 40 by a detector 38, and a decoder 42 converts it into a binary signal. Therefore, high S/N and information density equal to that of binary saturation recording are obtained by the saturation recording. The convolutional code of the rate 1 is used, and therefore information recorded on the medium by using absolutely minimum code symbols can be encoded while given redundancy to simplify timing control.



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CLAIMS

[Claim(s)]
[Claim 1] The coding approach characterized by outputting the remainder term train which consists of the 1st, 2nd, and 3rd 3 value sign as 3 value signs by inputting the bit string showing the 1st or 2nd binary sign into memory, storing an impulse response vector in this memory, and collapsing and processing this bit string by this vector, and carrying out division-process processing of the result of this convolution processing by 3.
[Claim 2] The coding approach according to claim 1 characterized by this convolution and division-process processing performing this bit string through the array of a logic gate.
[Claim 3] The coding approach of claim 1 characterized by having a term corresponding to each bit used in order for this vector to collapse and to decide a term, and for this convolution and division-process processing being expressed by this 1st sign, and including the bit by which convolution processing is carried out, and the processing which adds this corresponding term by the modulo 3.
[Claim 4] It is the approach of recording this remainder term train by the coding approach according to claim 1 on a magnetic medium. When it has the step which determines 3 value signs to which this specific remainder term is expressed to each specific **** and this specific remainder is expressed with 3 value signs of 1st **** 2 by this decision, The record approach of 3 value signs characterized by performing processing which determines 3 value signs of each remainder of this so that this magnetic medium may be in a magnetic neutral state substantially when this specific remainder is expressed by that of 3rd 3 value sign by this decision so that this magnetic medium may have the magnetization condition of the 1st or 2nd direction, respectively.
[Claim 5] this -- the record approach of 3 value signs according to claim 4 characterized by the 1st and 2nd magnetization conditions being saturation states magnetically substantially.
[Claim 6] this -- the record approach of 3 value signs according to claim 5 characterized by the 1st and 2nd magnetization conditions being reversed polarity substantially.
[Claim 7] Only the time amount which was able to determine the 1st and 2nd magnetization conditions beforehand is produced by impressing the 1st and 2nd field of reversed polarity to this medium substantially in the same magnitude. this -- The record approach of 3 value signs according to claim 4 characterized by producing only the time amount which was able to determine this magnetic neutral state beforehand by impressing reversal of the field of multiple times including impressing this 1st field to this medium, and subsequently impressing this 2nd field.
[Claim 8] The record approach of 3 value signs according to claim 7 characterized by the magnetic reversal of these multiple times including at least three reversal.
[Claim 9] The sign record approach according to claim 7 characterized by making it generated by passing a current in the coil which approached this medium in this field.
[Claim 10] this -- the sign record playback approach according to claim 7 characterized by including further the playback step which reproduces the 1st and 2nd binary signs from this magnetic-recording medium.
[Claim 11] The sign record playback approach according to claim 10 that this playback step detects this magnetization condition, and is characterized by including equalizing and decoding this magnetization condition to this binary sign further.
[Claim 12] The sign record approach according to claim 11 characterized by this decode including use of the Viterbi technique.
[Claim 13] The storage step which is the approach of encoding the bit string which consists of a bit showing the 1st or 2nd binary sign, and memorizes 1 bit at a time for this bit string for every cel to the array of two or more storage cells, The preparation step which prepares

the vector of the term which made the term with the 1st, 2nd, and 3rd numeric value correspond to each cel to each cel, The coding approach characterized by having the addition step which obtains the 1st result which takes the sum by the modulo 3 and is expressed by 1st, 2nd, and 3rd 3 value sign by that cause in this term corresponding to this cel that has a bit showing the binary sign of this beginning.

[Claim 14] The shift step which this train has the cel of the 1st and the last, and shifts this bit in this cel to a near contiguity cel by the cel of this beginning except for the cel of this beginning further, The coding approach according to claim 13 characterized by having the step which takes the sum for this term corresponding to this cel that has the bit which expresses the binary sign of this beginning as the storing step which stores the new bit showing the 1st or 2nd binary sign in this last cel by the modulo 3.

[Claim 15] It has the step which determines 3 value signs to which this 1st result is expressed in case this 1st result is recorded on a magnetic medium. It is determined that this 1st result is expressed with 3 value signs of 1st **** 2 that this magnetic medium has the magnetization condition of the 1st or 2nd direction, respectively. The sign record approach according to claim 13 characterized by determining that this 1st result is expressed with 3rd 3 value sign that this magnetic medium will be in a magnetic neutral state substantially.

[Claim 16] this -- the sign record approach according to claim 15 characterized by the 1st and 2nd magnetization conditions being saturation states magnetically substantially.

[Claim 17] this -- the sign record approach according to claim 16 characterized by the 1st and 2nd magnetization conditions being reversed polarity substantially.

[Claim 18] Only the time amount which was able to determine the 1st and 2nd magnetization conditions is produced by impressing the 1st and 2nd field of reversed polarity to this medium substantially in the same magnitude. this -- Moreover, the sign record approach according to claim 15 characterized by producing only the time amount which was able to determine this condition of not being magnetized by impressing reversal of the field of multiple times including impressing this 1st field to this medium, and subsequently impressing this 2nd field.

[Claim 19] The sign record approach according to claim 18 characterized by field reversal of these multiple times including at least three reversal.

[Claim 20] The sign record approach according to claim 18 characterized by producing these 1st and 2nd fields by passing in the coil which approached this medium in the forward and negative current, respectively.

[Claim 21] it was recorded by the sign record approach according to claim 15 -- this -- the sign record playback approach characterized by including the playback step which reproduces the 1st and 2nd binary signs from this magnetic-recording medium.

[Claim 22] The sign record playback approach according to claim 21 characterized by including that this playback step decodes detecting and equalizing this magnetization condition and this magnetization condition to this binary sign.

[Claim 23] The sign record playback approach according to claim 22 characterized by this decode using the Viterbi technique.

[Claim 24] The sign record playback approach of claim 22 characterized by this detection and identification using partial response identification.

[Claim 25] The sign record playback approach according to claim 22 characterized by this detection and identification including use of PURIKODINGU and peak detection identification.

[Claim 26] The sign record playback approach of claim 22 characterized by this detection and identification using judgment feedback mold identification.

[Claim 27] The magnetic-recording approach characterized by being the approach of recording the 1st, 2nd, and 3rd sign on a magnetic-recording medium, expressing this 1st sign by turning this medium in the 1st magnetization direction, and expressing this 2nd sign by turning this medium in the 2nd magnetization direction, and expressing this 3rd sign by making this medium into a magnetic neutral state substantially.

[Claim 28] this -- the magnetic-recording approach according to claim 27 characterized by the 1st and 2nd magnetization conditions being saturation states magnetically substantially.

[Claim 29] this -- the magnetic-recording approach according to claim 27 characterized by the 1st and 2nd magnetization conditions being reversed polarity substantially.

[Claim 30] The 1st and 2nd magnetization conditions produce only the fixed time amount by impressing the 1st and 2nd field of reversed polarity to this medium substantially in the same magnitude. this -- The magnetic-recording approach according to claim 27 characterized by making it generated by impressing reversal of the field of the multiple times in which this magnetic neutral state includes that only the fixed time amount impresses this 1st field to

this medium, and subsequently impresses this 2nd field.
[Claim 31] The magnetic-recording approach according to claim 30 characterized by field reversal of these multiple times including at least three reversal.
[Claim 32] this -- the magnetic-recording approach according to claim 30 that the 1st and 2nd record fields are characterized by being generated by passing the each forward and a negative current in the coil close to a medium.
[Claim 33] further -- this -- the magnetic-recording playback approach according to claim 30 characterized by including playback SUTEPPU ** which reproduces the 1st and 2nd binary sign from this magnetic-recording medium.
[Claim 34] The magnetic-recording playback approach according to claim 33 characterized by including that this playback step decodes detecting and equalizing this magnetization condition and this magnetization condition to this binary sign.
[Claim 35] It is equipment which records the train of the bit showing the 1st or 2nd binary sign on a magnetic-recording medium. A coding means to encode this bit string as 3 value trains of 1st, 2nd, and 3rd 3 value sign, And the magnetic recording medium characterized by having the 1st or 2nd magnetization condition or record means substantially made into a magnetic neutral state of a direction for this medium corresponding to 1st, 2nd, and 3rd 3 value sign according to the output of this coding means, respectively.
[Claim 36] The magnetic recording medium according to claim 35 characterized by this coding means having a division means to generate the remainder train which collapses this bit string and an impulse response vector, divides each of this convolution result by 3 in response to this convolution means to generate the train of a convolution result, and this convolution result, and is expressed with 1st, 2nd, and 3rd 3 value sign.
[Claim 37] The magnetic recording medium according to claim 36 characterized by this convolution means and this division-process means being integrated by the array of a logic gate.
[Claim 38] The magnetic recording medium according to claim 36 characterized by this convolution means and this division-process means being integrated by the microprocessor.
[Claim 39] A storing means to store this a part of bit string in the array of the cel which this coding means becomes from a 1 bit [per cel] cel, The array of the element of the term as which the 1st which the term corresponding to each cel exists and expresses an impulse response vector, the 2nd, and the 3rd were evaluated which it combines and has, this -- the magnetic recording medium according to claim 35 characterized by having a means to generate the 1st result which adds this term corresponding to this cel with the bit showing the 1st binary sign by the modulo 3, and is expressed with 1st, 2nd, and 3rd 3 value sign by that cause.
[Claim 40] A means for the array of this cel to have the cel of the first and the last, and to shift this bit in this cel to a near contiguity cel by this 1st cel except for this first cel, A storing means to store the new bit from this bit string in this last cel, this -- the magnetic recording medium according to claim 39 characterized by having an addition means to generate the 2nd result which adds this term corresponding to this cel with the bit showing the 1st binary sign by the modulo 3, and is expressed with 1st, 2nd, and 3rd 3 value sign by that cause.
[Claim 41] The magnetic recording medium according to claim 40 characterized by this storing means being a register.
[Claim 42] The magnetic recording medium according to claim 40 characterized by this storing means being a shift register.
[Claim 43] The magnetic recording medium according to claim 40 characterized by this storing means being random access memory.
[Claim 44] The magnetic recording medium according to claim 39 characterized by this addition means being a microprocessor.
[Claim 45] The magnetic recording medium according to claim 39 characterized by this addition means being the combination of a logic gate.
[Claim 46] Further, this record means so that it may have 3 value magnetization condition in which the 1st and the 2nd carried out orientation magnetically [this 1st result] [the decision means and this medium for determining with any of these 3 value signs it is expressed] So that it may have the 1st means following deciding whether this 1st result is expressed with this 1st or 2nd sign, and 3 value magnetization condition that orientation of this medium is not carried out magnetically substantially The magnetic recording medium according to claim 35 characterized by having the 2nd means following deciding whether this 1st result is expressed with this 3rd sign.

[Claim 47] this -- the [illegible]etic recording medium according to clai[illegible] characterized by the 1st and 2nd magnetization conditions being saturation states magnetically substantially.
[Claim 48] this -- the magnetic recording medium according to claim 47 characterized by the 1st and 2nd magnetization conditions being reversed polarity substantially.
[Claim 49] this 1st means -- this -- the 1st and 2nd magnetization conditions only the decided time interval It is the means produced by impressing the 1st and 2nd field of reversed polarity to this medium substantially in the same magnitude. this -- the magnetic recording medium according to claim 46 with which this 2nd means is characterized by being a means to make this magnetic neutral state cause by impressing reversal of the field of multiple times including only the decided time interval impressing this 1st field to this medium, and subsequently this magnetic neutral state impressing this 2nd field.
[Claim 50] The magnetic recording medium according to claim 49 characterized by field reversal of these multiple times including at least three reversal.
[Claim 51] this 1st and 2nd means -- this -- the magnetic recording medium according to claim 49 characterized by the 1st and 2nd record field being what produced by passing a forward and negative current in the coil close to this medium, respectively.
[Claim 52] The magnetic recording medium according to claim 46 characterized by having the high frequency signal oscillator connected to the array and this array of a logic gate, and this decision means, this 1st means, and this 2nd means being integrated by the array of this logic gate.
[Claim 53] The magnetic recording medium according to claim 46 characterized by this decision means, this 1st means, and this 2nd means being integrated by this microprocessor including a microprocessor and the RF signal oscillator connected to this microprocessor.
[Claim 54] it has the 1st or 2nd magnetic orientation condition for the decision means and this medium for deciding these which 3 value signs should be recorded, respectively -- as -- this -- whether the 1st or this 2nd sign should be recorded with the 1st means following determining The magnetic recording medium which records the 1st, 2nd, or 3rd sign characterized by having the 2nd means following determining whether this 3rd sign should be recorded as this medium makes it a magnetic neutral state magnetically substantially.
[Claim 55] this -- the magnetic recording medium according to claim 54 characterized by the 1st and 2nd magnetization conditions being saturation states magnetically substantially.
[Claim 56] this -- the magnetic recording medium according to claim 55 characterized by the 1st and 2nd magnetization conditions being reversed polarity substantially.
[Claim 57] this 1st means -- this -- the 1st and 2nd magnetization conditions only the fixed time amount It is made to be generated by impressing the 1st and 2nd field of reversed polarity to this medium substantially in the same magnitude. The magnetic recording medium according to claim 54 characterized by having this 2nd means for making this magnetic neutral state cause by impressing reversal of the field of multiple times including only the time interval this 2nd means was decided to be impressing this 1st field to this medium, and subsequently impressing this 2nd field.
[Claim 58] The magnetic recording medium according to claim 57 characterized by field reversal of these multiple times including at least three reversal.
[Claim 59] passing a forward and negative current in the coil with which these 1st and 2nd means approached this medium -- respectively -- this -- the magnetic recording medium according to claim 57 characterized by producing the 1st and 2nd record fields.
[Claim 60] The magnetic recording medium according to claim 54 characterized by having had a microprocessor and the RF signal oscillator connected to this microprocessor, and accumulating this decision means, this 1st means, and this 2nd means on this microprocessor.
[Claim 61] The magnetic recording medium according to claim 54 characterized by having further the combination of a logic gate, and the RF signal oscillator connected to this association, and this decision means, this 1st means, and this 2nd means being integrated by the combination of this logic gate.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the coding approach and magnetic recording medium which use 3 value channels in case [if it says in more detail,] digital data will be memorized to a magnetic storage medium, a digital magnetic-recording system and.
[0002]
[Description of the Prior Art] By arrival of the information age, the demand is also very strong to storage of digital data with the rise of the demand to digital information processing. Since it corresponds to this growing demand, it is required to raise the recording density of the information memorized by each magnetic recording medium. For example, the capacity of a magnetic disk drive was reinforced by one 10 times the rate of this in the past 30 years in ten years. This explosive increment was brought about with some elements. Namely, mark They are proceedings by dirty . KURAIDA. OBUAIIII Like the publication in "introduction of a magnetic information storage technical special edition" of the 1986 or November issue and a 1475-1476 pages (Mark H.Kryder, Proceeding of the IEEE, pp.1475-1476, November 1986.) announcement, there is improvement in the positioning accuracy for ****** of the gap length and the flying height in detailed-izing of the magnetic particle in the amelioration on the design of a head or a disk and disk media and a head and the improvement in track density.
[0003] When recording correctly on a magnetic storage medium, about using the sign more than binary [which is expressed with "0" and "1"], there was no advance substantially. However, at least four attempts to which storage capacity is made to increase are made by recording a sign on 3 value channels for which three signs, "0", "1", and "2", are used.
[0004] The 1st technique of recording information magnetically using 3 value magnetic-recording channel He is IEEE by an R . price etc. Transactions ON MAGUNE tex, September, 1978, 14 MAGU, No. 5, it was announced by 315-317 pages (R.Price et al.IEEE Transaction on Magnetics, vol.mag.-14, no.5, pp.315-317, and September 1978) -- " -- experimental and a multiple value -- It is high-density disk storage system." The price etc. adopted AC bias, in order to linearize a magnetic-recording channel, and it recorded the signal of 3 level on the magnetic-recording medium. Magnetization of a medium is restricted to level quite lower than saturation by the demand of linearization. That is, magnetization serves as low level from the condition of having gathered in the specific direction with all the magnetic particles in some media. Consequently, higher information density can be attained to a S/N ratio with the higher saturation record by the binary channel, and the existing error frequency which was decided.
[0005] The 2nd approach of recording information magnetically using 3 value magnetic-recording channel George Buoy . He is IEEE by YAKOBI. Transactions ON MAGUNE tex, November, 1981, 17 MAGU, No. 6, Were announced by 3326-3328 pages (Geoge V.Jacoby Transactions on Magnetics, vol.mag.-17, no.pp.3326-3328, and November 1981). They are "3 Value 3PM magnetic-recording sign and system." Jacobi is a single pulse and double. The binary saturation record with flux reversal which generates three output waves without a pulse and a pulse was used.
[0006] The 3rd approach of recording information magnetically using 3 value magnetic-recording channel He is IEEE by C . S . tsi and KE . A . Frei. Tolan ZAKUSHONZUN MAGUNE tex, November, 1982, 18 MAGU, No. 6, 1259-1261 pages () [C.S.Chi] and K.A.Frei Were announced by IEEE Transactions on Magnetics, vol.mag.-18, no.6, pp.1259-1261, and November 1982. It is "3 Directivity CRA for value digital recording." Tsi etc. used continuous AC record signal. Three value signs were encoded by inserting suitable "chip" for AC signal. AC signal is recovered after a short time and a "chip" when AC signal reaches maximum is a "forward" doublet. A pulse is generated. Similarly, a "chip" in case AC signal is the minimum value is a "negative"

doublet. Generating a pulse, those without a "chip" do not produce a doublet. The doublet which consists of two flux reversal needs to be used for both channels described by YAKOBI, tsi, etc. Since it is necessary to detach flux reversal enough to form a doublet, the magnitude of a doublet decides the sign consistency of a record channel it. Therefore, there is no net gain compared with the conventional binary saturation record technique, or even if it is the point of information density, there is only very slight net gain.

[0007] The 4th approach of recording information magnetically using 3 value magnetic-recording channel KATERINU He is IEEE by A . French etc. Transactions ON MAGUNE tex, September, 1987, 23 MAGU, No. 5, 3678-3680 pages () [Catherine] A.French et al. IEEE Transactions on Magnetics, vol.mag.-23, and no. --" (D --) announced by 5, pp.3678-3680, and September 1987. K) It is "as a result of including a Mth limit sign.

[0008] By this channel, the wave-like peak detected by this eases the request of the saturation magnetic recording that that polarity changes by turns, using the flux reversal densely placed instead of the chip of flux reversal so that it might deny. By deletion of this request, a saturation magnetic-recording channel can serve as three values without not binary [by the existence of a peak] but forward, a negative peak, and a peak. This channel can be regarded as the escape of the binary channel of an indication to United States patent USP3,227,454 by Chao. "Zero" are expressed with even flux reversal and "1" is expressed by this approach by odd flux reversal.

[0009] Since this approach has limit -, for example, - to which at least one "zero" must exist between the same polar peaks, in order of 3 value signals inputted into a channel, it is not 3 true value channels. In order to be dependent on the information pattern with which the data memorized are recorded, processing is nonlinear, therefore a modulation is complicated. Therefore, compared with the binary saturation record technique from the former, most or a real target does not have the improvement which can be attained in respect of information density.

[0010] There is a reduction demand of the error occurrence frequency corresponding to [very in addition to the big demand] large-capacity-izing to such storage to information storage capacity. Therefore, the utilization of coding which can respond to a timing extract, nonlinear reduction, and an error correction is required in many things.

[0011] Although there is much technique in informational coding, by almost all magnetic-recording media, the "run length limit" (RLL) sign is used for a timing extract and nonlinearity reduction. The max and min of two continuous flux reversal spacing, i.e., spacing of direction change of the magnetization on a magnetic-recording medium, are controlled by the RLL sign. When the maximum spacing was decided, it is guaranteed in response to renewal of a timing signal with the frequent timing extract function in a detector that loss of a signal can be avoided. Since updating is performed only when there is a signal in which detection like flux reversal is possible, it needs to be guaranteed that such a signal appears frequently and periodically. In high recording density, it is maintained so that flux reversal may not approach too much with the minimum flux reversal spacing. If flux reversal approaches too much, interference will be caused so that signal amplitude not only decreases, but it may shift from the location where the signal was recorded. Consequently, timing Nonlinear effect which the probability of an error increases arises.

[0012] Detection of an error of the information recorded on the magnetic-recording medium and correction are carried out to recording information by the redundancy addition at the time of coding. In order to add redundancy, it is required to add the signal of a certain amount and to record on a medium to the information on a certain amount. In order to avoid the fall of the information density on a medium, it is necessary to record a signal more densely, and it is a raw error as a result. A rate is worsened.

[0013] A certain error Although it is important, since it is influenced by the coding approach, the information density to a rate is a code. The index of the consistency expressed as a rate was developed. Code Generally a rate is defined by the number of information bits of the average corresponding to each channel signaling. Therefore, the binary channel with two signals expressed with binary "0" and "1" is a code when there is no redundancy of coding. Rate = it is set to 1. Coding is a code [as opposed to / since it has redundancy / a binary sign]. Generally a rate always becomes a value between 1/2 and 3/4 one or less. A high code like eight ninths A rate takes the balance of redundancy to information density, and is attained.

[0014] The technique from the former is used by the decode approach replaced with it. By the doctoral dissertation in 1975 in the cull FORUNIA state university loss ANJIERUSU school which entitles "the convolutional code for the Mth channels", BI . Di . tolan pass (B. D.Trumpis)

studied application of the convolutional code by which the coded signal was extended to the Mth sign. M is the integer of the exponentiation of 2 here. He changed the convolutional code into the Mth signal from binary, and while this maintained the code rate 1, he gave required redundancy. However, since the Mth realizable channel sign was not developed to magnetic recording, it is a code. The advantage of the convolutional code of a rate 1 is not realized yet.

[0015]

[Problem(s) to be Solved by the Invention] For the purpose of this invention, information is a code at least. An error is made in densification, i.e., large-capacity-izing, by encoding at a rate 1, a magnetic-recording medium memorizing, and saturation magnetic recording being used, having a flux reversal consistency equivalent to a binary channel, and making possible the system which can be modeled as a linear system. It is attaining securing a rate.

[0016]

[Means for Solving the Problem] Code equipped with the flux reversal consistency comparable as the binary channel by saturation magnetic recording in order to attain the above-mentioned purpose The coding system of a rate 1 is realized. This coding system can be modeled with a linear system. By making the above-mentioned technique into a starting point, in order to equip a system with 3 value channels and to secure the information-redundancy nature recorded, convolutional code-ization is used.

[0017] In the desirable example, this invention system encodes the bit string showing the 1st or 2nd binary sign. The impulse response vector in which each term has the 1st, 2nd, and 3rd numeric value is used. The above-mentioned bit string is collapsed with the above-mentioned vector, the value which carried out division of the value by 3 is generated, and the remainder expressed with 1st, 2nd, and 3rd 3 value sign is generated.

[0018] Moreover, this invention system records above 1st, 2nd, and 3rd 3 value sign on a magnetic-recording medium. 1st and 2nd 3 value sign is recorded by corresponding a magnetic-recording medium to the condition of the 1st and the 2nd magnetization, respectively. The 3rd sign is recorded when making it the above-mentioned record medium be in a magnetic neutral state substantially.

[0019] this invention system has the part which reproduces further the information recorded on the above-mentioned record medium. The 3 above-mentioned value signs are detected (identification carried out further), are read as a ** pulse, and are decoded by the train of the original binary sign from 3 value signals after that.

[0020]

[Function] In this invention, since saturation record was used, in the given error occurrence frequency, a conventional high S/N ratio and information density comparable as what can be attained by binary record are obtained. Since there is no need of taking spacing between channel signs which permit a doublet, thereby, an information storing consistency can improve. Furthermore, since this invention can carry out modeling possible as a linear system, it can use a linear equalization machine [that it is easy and low cost / technique / over a nonlinear channel / identification]. The thing of the coding alphabet for which the convolutional code of the code rate 1 is used is possible further again, guaranteeing the minimum expansion absolutely. Moreover, since the sign of the code rate 1 was used, the information outputted from the input to a binary-3 value encoder and a 3 value-binary decoder is the same code rate, therefore control of timing is simplified.

[0021]

[Example] An example explains to a detail below.

[0022] The magnetic-recording system 10 of this invention is shown in drawing 1 . In order to record a binary signal on a magnetic-recording medium and to reproduce, the magnetic-recording channel of the convolutional code from binary to three values and three values is used for this system.

[0023] In drawing 1 , the binary signal (namely, bit string) of a signal line 12 is inputted into an encoder 14, and the above-mentioned binary signal is changed into 3 value signals there using a convolutional code. Three value signals 13 are outputted to the record logic section 18 from an encoder 14, as shown by the line 16. The record logic section 18 generates the current signal of forward, negative, or an alternating current corresponding to the 3 above-mentioned value signals. The above-mentioned current signal is outputted to the well-known record amplifier 22 from the record logic section 18, as shown by the line 20. The record amplifier 22 amplifies the above-mentioned current, and as a line 24 shows, it outputs it to the well-known recording head 26. A recording head 26 records the above-mentioned current signal on the well-known digital magnetic-recording medium 28 used for information

storage. The reproducing head 30 outputs a voltage output to a preamp 34, as it is reproduced by the reproducing head 30 and a line 32 shows the signal memorized by the medium 28. A preamp 34 amplifies the voltage signal, and as a line 36 shows, it outputs the amplified output to a detector 38. A detector 38 outputs 3 value signals to a decoder 42, as the amplified voltage signal is changed into 3 value signals and a line 40 shows it. A decoder 42 changes the 3 value signal into a binary signal, and outputs a binary signal to a line 44.

[0024] As for drawing 2 and drawing 3 (a), (b), and (c), restricted length (K) shows the component of the convolutional code machine 14 from binary [of 7] to three values. In drawing 2 , an encoder 14 has the binary adder 204 of the set of a shift register 200, pass, a shift, and the zero (PSZ) element 202, and a modulo 3. An adder 204 may be a microprocessor. A register 200 is driven with the clock pulse signal generated by the timer clock generator (not shown) including seven cels 200a-200g for memorizing seven bits. While only one cel is shifted from cel 200b to 200g, the new bit of a signal line 12 is inputted and the bit stored in 200g from cel 200a whenever each clock pulse came is memorized by cel 200a, the bit memorized by cel 200g before disappears. As for the set 202 of PSZ, the copy of the cel 200a to 200g contents passes these elements from seven element 202a to juxtaposition including 202g.

[0025] In drawing 3 (a), (b), and (c), a program is possible so that 202g each may operate separately in pass, a shift, and zero mode from element 202a. element 202a from -- 202g When it is in pass mode (drawing 3 (a)), the bit "1" copied from corresponding cel 202a-202g or "0" "is passed", and each 00 or 01 is inputted into an adder 204. To it, when element 202a-202g is in shift mode (drawing 3 (b)), the bit "0" copied from corresponding cel 202a-202g or "1" is shifted, and 00 or 10 is respectively inputted into an adder 204. When element 202a-202g is in zero mode (drawing 3 (c)), although the bit corresponding to cel 202a-202g is "0" or "1", 00 is independently inputted into an adder 204.

[0026] The optimal input vectors which make an error min in a system 10 are [1, 1, 1, 2, 0, 2, 2] in the decimal number system. With reference to drawing 2 , this vector can be performed by making 202g pass, pass, pass, a shift, zero, a shift, and a shift from PSZ element 202a, respectively. By each shift of a register 200, an adder 204 asks for the sum of the input from PSZ element 202a-202g, divides the sum by 3, and outputs a remainder (binary 00, 01, 10) to output lines 16a and 16b. Operating so that 202g may be carried out in this way from PSZ element 202a and 3 value impulse response vector may be saved, an adder 204 serves to collapse the binary contents of a register 200 to 3 value impulse response vector. As the result, the binary input signal of the input signal line 12 is changed into 3 value signals which consist of a pair of (it corresponds to three signs) 2-bit trains, and is outputted to output lines 16a and 16b.

[0027] Drawing 4 shows logic actuation of the record logic section 18, and the logic section has the well-known high frequency oscilator 400, AND gate 402, OR gate 404, and a well-known voltage amplifier and the well-known bias generator 406. An oscillator 400 generates the signal desirably oscillated by one 4 to 6 times the frequency of the clock rate of a system of this. The AND gate 402 takes the AND of the output of an oscillator 400, and the reversal signal of signal lines 16a and 16b. The OR gate 404 takes the OR of the output of the AND gate 402, and the signal of signal-line 16a. Thus, the output signal of the OR gate 404 corresponds to each that the signals of signal lines 16a and 16b are 00, 01, and 10 in a binary signal, and it becomes an oscillation signal, the Law signal, and a high signal. The output signal of the OR gate 404 is inputted into components 406, and although bias is carried out and yes and low signals are magnification and the same amplitude which is expressed with +1 and -1 about a signal there, respectively, it becomes the thing of reversed polarity. The voltage signal generated with components 406 is outputted to the record amplifier 22 through a signal line 20.

[0028] The record amplifier 22 is amplified in sufficient magnitude for a recording head 26 to record a signal for the signal of a signal line 20 at the magnetic-recording medium 28. Any of the amplifier which is used widely and is well known for the magnetic-recording system, especially the digital magnetic-recording system, and a head are sufficient as an amplifier 22 and a head 26. When a yes (+1) or low (-1) signal is inputted into a recording head 26, well-known saturation record is used, and thereby, a field is altogether impressed substantially [a particle] in some specific regions of a medium 28 so that it may be equal to one of the magnetization conditions (polarity) of two opposite directions in magnetization. When a zero (oscillation) signal is inputted into a recording head 26, a vibration-field is impressed so that magnetization of the particle in the specific subregion of a medium 28 may carry out orientation at random, and it will be in the condition that there is no magnetization as the whole as a result. Yes, that is, a low signal is eliminated by the

vibration-signal in the region of a medium 28. This can be said to be being record of the information using the condition of a channel to record by the flux reversal of the conventional channel.

[0029] The information is reproduced with the well-known reproducing head 30 and a well-known preamp 34 after record of the information on the magnetic-recording medium 28. It is the technique in which both were known well and is widely available. The reproducing head 30 generates the voltage signal corresponding to the magnetization on a medium 28. A preamp 34 amplifies the voltage output reproduced by the reproducing head 30 to the suitable amplitude, and outputs a signal to a signal line 36.

[0030] The current wave form 600 recorded on drawing 6 by the medium by the recording head 26 corresponding to a channel condition train (+ 1, 0, + 1, 0, - 1, +1, +1, - 1, 0, +1) is shown. The voltage waveform 602 (it is equivalent to the inexact differential of a channel condition) corresponding to a record current read by the reproducing head 30 is united with the record current wave form 600, and is shown.

[0031] Even if it uses a microprocessor (not shown), the possible detector 38 receives the voltage signal of a signal line 36, and equalizes it using the judgment feedback mold equalizer (DFE) technique for every well-known sign desirably. By using DFE, the voltage signal is sampled and an intersymbol interference (effect on a specific sign with ISI and a contiguity sign) is removed. Consequently, an ideal sampled-value train is outputted substantially and 3 value signs by which identification was carried out are outputted to a signal line 40 from a detector 38. The DFE technique expressed here is known well and is a large utilizable technique. 3 value signs of a signal line 40 -- the sign of a signal line 16 -- the same -- a bit pair (binary sign) -- it is expressed with 00, 01, and 10.

[0032] Three value signs from a detector 38 are decoded by the binary sign with a decoder 42. As for a decoder 42, it is desirable to use the well-known Viterbi technique (or the degeneration type of thing). The binary sign train inputted into a signal line 12 and the binary sign train which is the same as an essential target are outputted to a signal line 44. A decoder 42 can also use a microprocessor (not shown).

[0033] Many formats and examples are possible for this invention. The example shown here is for explaining rather than it restricts invention, and can be deformed, without deviating from the pneuma and the range of invention. For example, if the encoder 14 shown in drawing 2 is taken for an example, the replacement to the storage element of other formats like random access memory (RAM) is possible for a shift register 200.

[0034] As another example, when 200g is being fixed by known from PSZ component 200a, a PSZ component and an adder 204 can be replaced at the logical circuit shown as an example shown in drawing 5 . Furthermore, the impulse response vector of the base 3 of description in the desirable example is possible in replacing with the other numbers of the bases, for example, the impulse response vector of the base 4.

[0035] As still more nearly another example, the thing using the small restricted length K can also carry out the convolutional code machine 14 more greatly than the die length of the restricted length K= 7 in a desirable example. The impulse response vector optimized by the minimum error can ask the restricted length K using the calculator program shown in drawing 7 . Such a program tests all the vectors of a Kth power individual of 3 by measuring a sink and the minimum error through the encoder which had all the binary trains from which 2*K may happen the die-length binary train which starts in the modeled encoder in 1 and is finished with it as K zero modeled. The vector which serves as max among the minimum errors is the optimal vector.

[0036] As still more nearly another example, change between channel conditions is used instead of the condition itself, and a sign can also be recorded on a medium. The DFE technique used for the detector 38 can also be reoccurred by other methods, for example, partial response method learned well, or peak detection methods for every sign, in order to reproduce the sign train recorded on the magnetic-recording medium. Other encoders are required in order PURIKODO [other 3 value trains showing the information by which the flux reversal was contained in the original sign train in 3 value sign trains / change or], when a peak detection method is used. By using a maximum-likelihood-decoding machine like the Viterbi detector (or the degeneration mold), a detector 38 and a decoder 42 may make it one component which was recorded on the magnetic-recording medium instead of the sign and which detects a series of relation and is decoded. Other data or information on formal which include the base of other numbers as still more nearly another example may be inputted into a signal line 12.

[0037] Although the example about invention was shown and explanation was added, the case where it is adopted without the special feature that this invention has correction of the

large range, modification, and insertion as opposed to the above-mentioned indication carrying out usage depending on which other special features corresponded may happen. Therefore, it should be interpreted as the claim written in addition being widely in agreement with the range of invention.

[0038]

[Effect of the Invention] This invention has many advantages to the conventional technique. Since saturation record was used for the 1st advantage, in the given error occurrence frequency, information density comparable as a high S/N ratio and the information density which can be attained by the binary record from the former is obtained. The 2nd advantage is a point whose information storage consistency can improve by that cause in order not to have the need of taking spacing between channel signs which permit a doublet. The 3rd advantage is a point which can be used by the linear equalization machine [that it is easier than the identification technique over a nonlinear channel since this invention can carry out modeling possible as a linear system, and low cost]. The 4th advantage is a point in which the thing of the coding alphabet for which the convolutional code of the code rate 1 is used is possible, guaranteeing the minimum expansion absolutely. Since the sign of the code rate 1 was used for the 5th advantage, the information outputted from the input to a binary-3 value encoder and a 3 value-binary decoder is the same code rate, therefore is a point in which simplification of control of timing is possible.

[Translation done.]

TECHNICAL FIELD

[Industrial Application] This invention relates to the coding approach and magnetic recording medium which use 3 value channels in case [if it says in more detail,] digital data will be memorized to a magnetic storage medium, a digital magnetic-recording system and.

[Translation done.]

PRIOR ART

[Description of the Prior Art] By arrival of the information age, the demand is also very strong to storage of digital data with the rise of the demand to digital information processing. Since it corresponds to this growing demand, it is required to raise the recording density of the information memorized by each magnetic recording medium. For example, the capacity of a magnetic disk drive was reinforced by one 10 times the rate of this in the past 30 years in ten years. This explosive increment was brought about with some elements. Namely, mark They are proceedings by dirty . KURAIDA. OBUAIIII Like the publication in "introduction of a magnetic information storage technical special edition" of the 1986 or November issue and a 1475-1476 pages (Mark H.Kryder, Proceeding of the IEEE, pp.1475-1476, November 1986.) announcement, there is improvement in the positioning accuracy for ****** of the gap length and the flying height in detailed-izing of the magnetic particle in the amelioration on the design of a head or a disk and disk media and a head and the improvement in track density.
[0003] When recording correctly on a magnetic storage medium, about using the sign more than binary [which is expressed with "0" and "1"], there was no advance substantially. However, at least four attempts to which storage capacity is made to increase are made by recording a sign on 3 value channels for which three signs, "0", "1", and "2", are used.
[0004] The 1st technique of recording information magnetically using 3 value magnetic-recording channel He is IEEE by an R . price etc. Transactions ON MAGUNE tex, September, 1978, 14 MAGU, No. 5, it was announced by 315-317 pages (R.Price et al.IEEE Transaction on Magnetics, vol.mag.-14, no.5, pp.315-317, and September 1978) -- " -- experimental and a multiple value -- It is high-density disk storage system." The price etc. adopted AC bias, in order to linearize a magnetic-recording channel, and it recorded the signal of 3 level on the magnetic-recording medium. Magnetization of a medium is restricted to level quite lower than saturation by the demand of linearization. That is, magnetization serves as low level from the condition of having gathered in the specific direction with all the magnetic particles in some media. Consequently, higher information density can be attained to a S/N ratio with the higher saturation record by the binary channel, and the existing error frequency which was decided.
[0005] The 2nd approach of recording information magnetically using 3 value magnetic-recording channel George Buoy . He is IEEE by YAKOBI. Transactions ON MAGUNE tex, November, 1981, 17 MAGU, No. 6, Were announced by 3326-3328 pages (Geoge V.Jacoby Transactions on Magnetics, vol.mag.-17, no.pp.3326-3328, and November 1981). They are "3 Value 3PM magnetic-recording sign and system." Jacobi is a single pulse and double. The binary saturation record with flux reversal which generates three output waves without a pulse and a pulse was used.
[0006] The 3rd approach of recording information magnetically using 3 value magnetic-recording channel He is IEEE by C . S . tsi and KE . A . Frei. Tolan ZAKUSHONZUN MAGUNE tex, November, 1982, 18 MAGU, No. 6, 1259-1261 pages () [C.S.Chi] and K.A.Frei Were announced by IEEE Transactions on Magnetics, vol.mag.-18, no.6, pp.1259-1261, and November 1982. It is "3 Directivity CRA for value digital recording." Tsi etc. used continuous AC record signal. Three value signs were encoded by inserting suitable "chip" for AC signal. AC signal is recovered after a short time and a "chip" when AC signal reaches maximum is a "forward" doublet. A pulse is generated. Similarly, a "chip" in case AC signal is the minimum value is a "negative" doublet. Generating a pulse, those without a "chip" do not produce a doublet. The doublet which consists of two flux reversal needs to be used for both channels described by YAKOBI, tsi, etc. Since it is necessary to detach flux reversal enough to form a doublet, the magnitude of a doublet decides the sign consistency of a record channel it. Therefore, there is no net gain compared with the conventional binary saturation record technique, or even if it is the point of information density, there is only very slight net gain.

[0007] The 4th approach of recording information magnetically usi[illegible] value magnetic-recording channel KATERINU He is IEEE by A . French etc. Transactions ON MAGUNE tex, September, 1987, 23 MAGU, No. 5, 3678-3680 pages () [Catherine] A.French et al. IEEE Transactions on Magnetics, vol.mag.-23, and no. --" (D --) announced by 5, pp.3678-3680, and September 1987. K) It is "as a result of including a Mth limit sign.

[0008] By this channel, the wave-like peak detected by this eases the request of the saturation magnetic recording that that polarity changes by turns, using the flux reversal densely placed instead of the chip of flux reversal so that it might deny. By deletion of this request, a saturation magnetic-recording channel can serve as three values without not binary [by the existence of a peak] but forward, a negative peak, and a peak. This channel can be regarded as the escape of the binary channel of an indication to United States patent USP3,227,454 by Chao. "Zero" are expressed with even flux reversal and "1" is expressed by this approach by odd flux reversal.

[0009] Since this approach has limit -, for example, - to which at least one "zero" must exist between the same polar peaks, in order of 3 value signals inputted into a channel, it is not 3 true value channels. In order to be dependent on the information pattern with which the data memorized are recorded, processing is nonlinear, therefore a modulation is complicated. Therefore, compared with the binary saturation record technique from the former, most or a real target does not have the improvement which can be attained in respect of information density.

[0010] There is a reduction demand of the error occurrence frequency corresponding to [very in addition to the big demand] large-capacity-izing to such storage to information storage capacity. Therefore, the utilization of coding which can respond to a timing extract, nonlinear reduction, and an error correction is required in many things.

[0011] Although there is much technique in informational coding, by almost all magnetic-recording media, the "run length limit" (RLL) sign is used for a timing extract and nonlinearity reduction. The max and min of two continuous flux reversal spacing, i.e., spacing of direction change of the magnetization on a magnetic-recording medium, are controlled by the RLL sign. When the maximum spacing was decided, it is guaranteed in response to renewal of a timing signal with the frequent timing extract function in a detector that loss of a signal can be avoided. Since updating is performed only when there is a signal in which detection like flux reversal is possible, it needs to be guaranteed that such a signal appears frequently and periodically. In high recording density, it is maintained so that flux reversal may not approach too much with the minimum flux reversal spacing. If flux reversal approaches too much, interference will be caused so that signal amplitude not only decreases, but it may shift from the location where the signal was recorded. Consequently, timing Nonlinear effect which the probability of an error increases arises.

[0012] Detection of an error of the information recorded on the magnetic-recording medium and correction are carried out to recording information by the redundancy addition at the time of coding. In order to add redundancy, it is required to add the signal of a certain amount and to record on a medium to the information on a certain amount. In order to avoid the fall of the information density on a medium, it is necessary to record a signal more densely, and it is a raw error as a result. A rate is worsened.

[0013] A certain error Although it is important, since it is influenced by the coding approach, the information density to a rate is a code. The index of the consistency expressed as a rate was developed. Code Generally a rate is defined by the number of information bits of the average corresponding to each channel signaling. Therefore, the binary channel with two signals expressed with binary "0" and "1" is a code when there is no redundancy of coding. Rate = it is set to 1. Coding is a code [as opposed to / since it has redundancy / a binary sign]. Generally a rate always becomes a value between 1/2 and 3/4 one or less. A high code like eight ninths A rate takes the balance of redundancy to information density, and is attained.

[0014] The technique from the former is used by the decode approach replaced with it. By the doctoral dissertation in 1975 in the cull FORUNIA state university loss ANJIERUSU school which entitles "the convolutional code for the Mth channels", BI . Di . tolan pass (B. D.Trumpis) studied application of the convolutional code by which the coded signal was extended to the Mth sign. M is the integer of the exponentiation of 2 here. He changed the convolutional code into the Mth signal from binary, and while this maintained the code rate 1, he gave required redundancy. However, since the Mth realizable channel sign was not developed to magnetic recording, it is a code. The advantage of the convolutional code of a rate 1 is not realized yet.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] This invention has many advantages to the conventional technique. Since saturation record was used for the 1st advantage, in the given error occurrence frequency, information density comparable as a high S/N ratio and the information density which can be attained by the binary record from the former is obtained. The 2nd advantage is a point whose information storage consistency can improve by that cause in order not to have the need of taking spacing between channel signs which permit a doublet. The 3rd advantage is a point which can be used by the linear equalization machine [that it is easier than the identification technique over a nonlinear channel since this invention can carry out modeling possible as a linear system, and low cost]. The 4th advantage is a point in which the thing of the coding alphabet for which the convolutional code of the code rate 1 is used is possible, guaranteeing the minimum expansion absolutely. Since the sign of the code rate 1 was used for the 5th advantage, the information outputted from the input to a binary-3 value encoder and a 3 value-binary decoder is the same code rate, therefore is a point in which simplification of control of timing is possible.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] For the purpose of this invention, information is a code at least. An error is made in densification, i.e., large-capacity-izing, by encoding at a rate 1, a magnetic-recording medium memorizing, and saturation magnetic recording being used, having a flux reversal consistency equivalent to a binary channel, and making possible the system which can be modeled as a linear system. It is attaining securing a rate.

[Translation done.]

MEANS

[Means for Solving the Problem] Code equipped with the flux reversal consistency comparable as the binary channel by saturation magnetic recording in order to attain the above-mentioned purpose The coding system of a rate 1 is realized. This coding system can be modeled with a linear system. By making the above-mentioned technique into a starting point, in order to equip a system with 3 value channels and to secure the information-redundancy nature recorded, convolutional code-ization is used.
[0017] In the desirable example, this invention system encodes the bit string showing the 1st or 2nd binary sign. The impulse response vector in which each term has the 1st, 2nd, and 3rd numeric value is used. The above-mentioned bit string is collapsed with the above-mentioned vector, the value which carried out division of the value by 3 is generated, and the remainder expressed with 1st, 2nd, and 3rd 3 value sign is generated.
[0018] Moreover, this invention system records above 1st, 2nd, and 3rd 3 value sign on a magnetic-recording medium. 1st and 2nd 3 value sign is recorded by corresponding a magnetic-recording medium to the condition of the 1st and the 2nd magnetization, respectively. The 3rd sign is recorded when making it the above-mentioned record medium be in a magnetic neutral state substantially.
[0019] this invention system has the part which reproduces further the information recorded on the above-mentioned record medium. The 3 above-mentioned value signs are detected (identification carried out further), are read as a ** pulse, and are decoded by the train of the original binary sign from 3 value signals after that.

[Translation done.]

OPERATION

[Function] In this invention, since saturation record was used, in the given error occurrence frequency, a conventional high S/N ratio and information density comparable as what can be attained by binary record are obtained. Since there is no need of taking spacing between channel signs which permit a doublet, thereby, an information storing consistency can improve. Furthermore, since this invention can carry out modeling possible as a linear system, it can use a linear equalization machine [that it is easy and low cost / technique / over a nonlinear channel / identification]. The thing of the coding alphabet for which the convolutional code of the code rate 1 is used is possible further again, guaranteeing the minimum expansion absolutely. Moreover, since the sign of the code rate 1 was used, the information outputted from the input to a binary-3 value encoder and a 3 value-binary decoder is the same code rate, therefore control of timing is simplified.

[Translation done.]

EXAMPLE

[Example] An example explains to a detail below.
[0022] The magnetic-recording system 10 of this invention is shown in drawing 1 . In order to record a binary signal on a magnetic-recording medium and to reproduce, the magnetic-recording channel of the convolutional code from binary to three values and three values is used for this system.
[0023] In drawing 1 , the binary signal (namely, bit string) of a signal line 12 is inputted into an encoder 14, and the above-mentioned binary signal is changed into 3 value signals there using a convolutional code. Three value signals 13 are outputted to the record logic section 18 from an encoder 14, as shown by the line 16. The record logic section 18 generates the current signal of forward, negative, or an alternating current corresponding to the 3 above-mentioned value signals. The above-mentioned current signal is outputted to the well-known record amplifier 22 from the record logic section 18, as shown by the line 20. The record amplifier 22 amplifies the above-mentioned current, and as a line 24 shows, it outputs it to the well-known recording head 26. A recording head 26 records the above-mentioned current signal on the well-known digital magnetic-recording medium 28 used for information storage. The reproducing head 30 outputs a voltage output to a preamp 34, as it is reproduced by the reproducing head 30 and a line 32 shows the signal memorized by the medium 28. A preamp 34 amplifies the voltage signal, and as a line 36 shows, it outputs the amplified output to a detector 38. A detector 38 outputs 3 value signals to a decoder 42, as the amplified voltage signal is changed into 3 value signals and a line 40 shows it. A decoder 42 changes the 3 value signal into a binary signal, and outputs a binary signal to a line 44.
[0024] As for drawing 2 and drawing 3 (a), (b), and (c), restricted length (K) shows the component of the convolutional code machine 14 from binary [of 7] to three values. In drawing 2 , an encoder 14 has the binary adder 204 of the set of a shift register 200, pass, a shift, and the zero (PSZ) element 202, and a modulo 3. An adder 204 may be a microprocessor. A register 200 is driven with the clock pulse signal generated by the timer clock generator (not shown) including seven cels 200a-200g for memorizing seven bits. While only one cel is shifted from cel 200b to 200g, the new bit of a signal line 12 is inputted and the bit stored in 200g from cel 200a whenever each clock pulse came is memorized by cel 200a, the bit memorized by cel 200g before disappears. As for the set 202 of PSZ, the copy of the cel 200a to 200g contents passes these elements from seven element 202a to juxtaposition including 202g.
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[0034] As another example, when 200g is being fixed by known from [illegible] component 200a, a PSZ component and an adder 204 can be replaced at the logical circuit shown as an example shown in drawing 5 . Furthermore, the impulse response vector of the base 3 of description in the desirable example is possible in replacing with the other numbers of the bases, for example, the impulse response vector of the base 4.
[0035] As still more nearly another example, the thing using the small restricted length K can also carry out the convolutional code machine 14 more greatly than the die length of the restricted length K= 7 in a desirable example. The impulse response vector optimized by the minimum error can ask the restricted length K using the calculator program shown in drawing 7 . Such a program tests all the vectors of a Kth power individual of 3 by measuring a sink and the minimum error through the encoder which had all the binary trains from which 2*K may happen the die-length binary train which starts in the modeled encoder in 1 and is finished with it as K zero modeled. The vector which serves as max among the minimum errors is the optimal vector.
[0036] As still more nearly another example, change between channel conditions is used instead of the condition itself, and a sign can also be recorded on a medium. The DFE technique used for the detector 38 can also be reoccurred by other methods, for example, partial response method learned well, or peak detection methods for every sign, in order to reproduce the sign train recorded on the magnetic-recording medium. Other encoders are required in order PURIKODO [other 3 value trains showing the information by which the flux reversal was contained in the original sign train in 3 value sign trains / change or], when a peak detection method is used. By using a maximum-likelihood-decoding machine like the Viterbi detector (or the degeneration mold), a detector 38 and a decoder 42 may make it one component which was recorded on the magnetic-recording medium instead of the sign and which detects a series of relation and is decoded. Other data or information on formal which include the base of other numbers as still more nearly another example may be inputted into a signal line 12.
[0037] Although the example about invention was shown and explanation was added, the case where it is adopted without the special feature that this invention has correction of the large range, modification, and insertion as opposed to the above-mentioned indication carrying out usage depending on which other special features corresponded may happen. Therefore, it should be interpreted as the claim written in addition being widely in agreement with the range of invention.

[Translation done.]

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(54)【発明の名称】　３値符号磁気記録システム

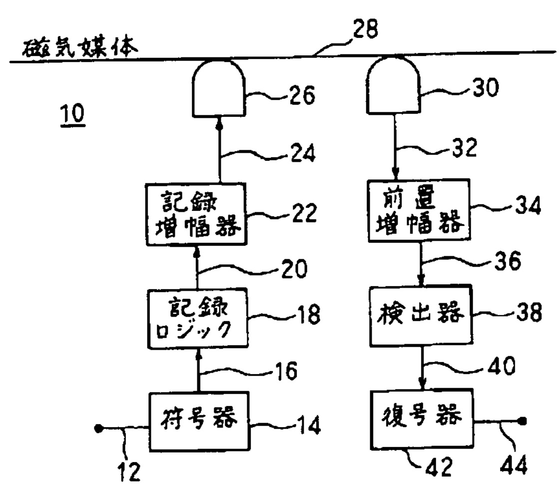
(57)【要約】

【目的】ディジタル情報記憶への容量増大するため、同一ヘッド、媒体を用いても、出来るだけ多くの情報が記憶することを可能にする情報符号化法、復号方法及びディジタル情報記憶装置を実現する。

【構成】磁気記憶システム１０において、２値入力信号１２をコードレート１の３値符号１６に復号し、記録ロジック部１８で３値符号を１、０、ＡＣの３つの状態に変換し、媒体２８に従来型記録ヘッド２６で飽和記録する。従来型再生ヘッド３０で読み出された信号３２は、増幅後、検出器３８でディジタル３値信号４０に検出し、復号器４２で２値信号に変換する。

【効果】飽和記録によって、高Ｓ／Ｎ比と２値飽和記録と同等の情報密度が得られる。レート１の畳み込み符号を用いているため、絶対的に最小の符号シンボルを用いて媒体に記録される情報に冗長性を持たせながら符号化でき、タイミング制御が簡素化できる。

図１



1

【特許請求の範囲】

【請求項1】第1又は第2の2値符号を表わすビット列をメモリに入力し、インパルス応答ベクトルを該メモリーに格納し、該ビット列を該ベクトルで畳み込み処理し、そして、該畳み込み処理の結果を3で割り算処理することによって、第1、第2、第3の3値符号からなる剰余項列を3値符号として出力することを特徴とする符号化方法。

【請求項2】該畳み込み及び割り算処理が該ビット列をロジックゲートの配列を通して行うことを特徴とする請求項1記載の符号化方法。

【請求項3】該ベクトルが畳み込み項を決めるために用いられる個々のビットに対応する項をもち、該畳み込み及び割り算処理が該第1の符号によって表され、畳み込み処理されるビットと対応する該項をモジュロ3で加算する処理を含むことを特徴とする請求項1の符号化方法。

【請求項4】請求項1記載の符号化方法による該剰余項列を磁気媒体に記録する方法であって、それぞれの特定余項に対し該特定剰余項が表される3値符号を決定するステップをもち、該決定で該特定の剰余が第1又第2の3値符号で表されるとき、該磁気媒体がそれぞれ第1又は第2の方向の磁化状態を持つように、該決定で該特定の剰余が第3の3値符号ので表されるとき、該磁気媒体が実質的に消磁状態になるように、該個々の剰余の3値符号を決める処理を行うことを特徴とする3値符号の記録方法。

【請求項5】該第1及び第2の磁化状態が実質的に磁気的に飽和状態であることを特徴とする請求項4記載の3値符号の記録方法。

【請求項6】該第1及び第2の磁化状態が実質的に逆極性であることを特徴とする請求項5記載の3値符号の記録方法。

【請求項7】該第1及び第2の磁化状態を、前もって決められた時間だけ、該媒体に実質的に同一の大きさで実質的に逆極性の第1、第2の磁界を印加することにより生じさせ、該消磁状態を、前もって決められた時間だけ、該媒体に該第1の磁界を印加し、次いで該第2の磁界を印加することを含む複数回の磁界の反転を印加することにより生じさせることを特徴とする請求項4記載の3値符号の記録方法。

【請求項8】該複数回の磁化の反転が少なくとも3回の反転を含むことを特徴とする請求項7記載の3値符号の記録方法。

【請求項9】該磁界を該媒体に近接したコイルに電流を流すことにより生じさせることを特徴とする請求項7記載の符号記録方法。

【請求項10】該第1及び第2の2値符号を該磁気記録媒体から再生する再生ステップを更に含むことを特徴とする請求項7記載の符号記録再生方法。

2

【請求項11】該再生ステップが、該磁化状態を検出し、等化し、更に該磁化状態を該2値符号に復号することを含むことを特徴とする請求項10記載の符号記録再生方法。

【請求項12】該復号がビタビ手法の利用を含むことを特徴とする請求項11記載の符号記録方法。

【請求項13】第1か第2の2値符号を表すビットからなるビット列を符号化する方法であって、該ビット列を複数の記憶セルのアレイにセル毎に1ビットづつを記憶する記憶ステップと、各セルに対し、第1、第2、第3の数値を持つ項をそれぞれのセルに対応させた項のベクトルを準備する準備ステップと、該最初の2値符号を表わすビットを有する該セルに対応した該項をモジュロ3で和をとり、それにより第1、第2、第3の3値符号により表わされる第1の結果を得る加算ステップをもつことを特徴とする符号化方法。

【請求項14】該列が第1及び最後のセルをもち、さらに該最初のセルを除き、該セル内の該ビットを該最初のセルにより近い隣接セルにシフトするシフトステップと、該最終セル内に第1又は第2の2値符号を表わす新しいビットを格納する格納ステップと、該最初の2値符号を表わすビットを持つ該セルに対応する該項をモジュロ3で和をとるステップをもつことを特徴とする請求項13記載の符号化方法。

【請求項15】該第1の結果を磁気媒体に記録するする際に該第1結果が表される3値符号を決定するステップをもち、該磁気媒体がそれぞれ第1又は第2の方向の磁化状態を持つように該第1結果が第1又第2の3値符号で表されるよう決定し、、該磁気媒体が実質的に消磁状態になるように該第1結果が第3の3値符号で表されるよう決定することを特徴とする請求項13記載の符号記録方法。

【請求項16】該第1及び第2の磁化状態が実質的に磁気的に飽和状態であることを特徴とする請求項15記載の符号記録方法。

【請求項17】該第1及び第2の磁化状態が実質的に逆極性であることを特徴とする請求項16記載の符号記録方法。

【請求項18】該第1及び第2の磁化状態を、決められた時間だけ、該媒体に実質的に同一の大きさで実質的に逆極性の第1、第2の磁界を印加することにより生じさせ、また該非磁化状態を、決められた時間だけ、該媒体に該第1の磁界を印加し、次いで該第2の磁界を印加することを含む複数回の磁界の反転を印加することにより生じさせることを特徴とする請求項15記載の符号記録方法。

【請求項19】該複数回の磁界反転が少なくとも3回の反転を含むことを特徴とする請求項18記載の符号記録方法。

【請求項20】該第1及び第2磁界をそれぞれ正及び負

の電流を該媒体に近接したコイルに流すことにより生じさせることを特徴とする請求項１８記載の符号記録方法。

【請求項２１】請求項１５記載の符号記録方法によって記録された、該第１及び第２の２値符号を該磁気記録媒体から再生する再生ステップを含むことを特徴とする符号記録再生方法。

【請求項２２】該再生ステップが該磁化状態を検出し等化すること及び該磁化状態を該２値符号に復号することを含むことを特徴とする請求項２１記載の符号記録再生方法。

【請求項２３】該復号がビタビ手法を利用することを特徴とする請求項２２記載の符号記録再生方法。

【請求項２４】該検出及び等化がパーシャルレスポンス等化を利用することを特徴とする請求項２２の符号記録再生方法。

【請求項２５】該検出及び等化がプリコーディング及びピーク検出等化の利用を含むことを特徴とする請求項２２記載の符号記録再生方法。

【請求項２６】該検出及び等化が判定帰還型等化を利用することを特徴とする請求項２２の符号記録再生方法。

【請求項２７】磁気記録媒体に第１、第２、第３の符号を記録する方法であって、該媒体を第１の磁化方向に向けることにより該第１の符号を表わし、該媒体を第２の磁化方向に向けることにより該第２の符号を表わし、そして該媒体を実質的に消磁状態にすることにより該第３の符号を表わすことを特徴とする磁気記録方法。

【請求項２８】該第１及び第２の磁化状態が実質的に磁気的に飽和状態であることを特徴とする請求項２７記載の磁気記録方法。

【請求項２９】該第１及び第２の磁化状態が実質的に逆極性であることを特徴とする請求項２７記載の磁気記録方法。

【請求項３０】該第１及び第２の磁化状態が、決められた時間だけ、該媒体に実質的に同一の大きさで実質的に逆極性の第１、第２の磁界を印加することにより生じさせ、該消磁状態が、決められた時間だけ、該媒体に該第１の磁界を印加し、次いで該第２の磁界を印加することを含む複数回の磁界の反転を印加することにより生じさせることを特徴とする請求項２７記載の磁気記録方法。

【請求項３１】該複数回の磁界反転が少なくとも３回の反転を含むことを特徴とする請求項３０記載の磁気記録方法。

【請求項３２】該第１及び第２の記録磁界が、媒体に近接したコイルにおのおの正、負の電流を流すことにより生じることを特徴とする請求項３０記載の磁気記録方法。

【請求項３３】さらに該第１、第２の２値符号を該磁気記録媒体から再生する再生ステップをを含むことを特徴とする請求項３０記載の磁気記録再生方法。

【請求項３４】該再生ステップが該磁化状態を検出し等化すること及び該磁化状態を該２値符号に復号することを含むことを特徴とする請求項３３記載の磁気記録再生方法。

【請求項３５】第１又は第２の２値符号を表わすビットの列を磁気記録媒体に記録する装置であって、該ビット列を第１、第２、第３の３値符号の３値列として符号化する符号化手段、及び該符号化手段の出力に応じて第１、第２、第３の３値符号に対応して該媒体をそれぞれ第１又は第２の方向の磁化状態又は実質的に消磁状態にする記録手段とをもつことを特徴とする磁気記録装置。

【請求項３６】該符号化手段が、該ビット列とインパルス応答ベクトルを畳み込み、畳み込み結果の列を発生させる該畳み込み手段、及び該畳み込み結果を受けて該畳み込み結果のそれぞれを３で割り、第１、第２、第３の３値符号で表わされる剰余列を発生させる割算手段をもつことを特徴とする請求項３５記載の磁気記録装置。

【請求項３７】該畳み込み手段と該割り算手段がロジックゲートの配列に集積化されたことを特徴とする請求項３６記載の磁気記録装置。

【請求項３８】該畳み込み手段と該割り算手段がマイクロプロセッサに集積化されたことを特徴とする請求項３６記載の磁気記録装置。

【請求項３９】該符号化手段が、セルあたり１ビットのセルからなるセルのアレイに該ビット列の一部を格納する格納手段と、個々のセルに対応する項が存在し、インパルス応答ベクトルを表わす第１、第２、第３の数値化された項の組み合わせ持つ要素のアレイと、該第１の２値符号を表わすビットを持つ該セルに対応する該項をモジュロ３で加算し、それにより第１、第２、第３の３値符号で表わされる第１の結果を発生する手段をもつことを特徴とする請求項３５記載の磁気記録装置。

【請求項４０】該セルのアレイは第一及び最後のセルを持ち、該第一のセルを除き、該セル内の該ビットを該第１のセルにより近い隣接セルにシフトする手段と、該最終セルに該ビット列からの新しいビットを格納する格納手段と、該第１の２値符号を表わすビットを持つ該セルに対応する該項をモジュロ３で加算し、それにより第１、第２、第３の３値符号で表わされる第２の結果を発生する加算手段をもつことを特徴とする請求項３９記載の磁気記録装置。

【請求項４１】該格納手段がレジスタであることを特徴とする請求項４０記載の磁気記録装置。

【請求項４２】該格納手段がシフトレジスタであることを特徴とする請求項４０記載の磁気記録装置。

【請求項４３】該格納手段がランダムアクセスメモリであることを特徴とする請求項４０記載の磁気記録装置。

【請求項４４】該加算手段がマイクロプロセッサであることを特徴とする請求項３９記載の磁気記録装置。

【請求項４５】該加算手段がロジックゲートの組み合わ

せであることを特徴とする請求項３９記載の磁気記録装置。

【請求項４６】該記録手段が更に該第１の結果が該３値符号のいずれで表されるかを決定するための決定手段と、該媒体が第１、第２の磁気的に配向した３値磁化状態を持つように、該第１の結果が該第１又は第２の符号で表わされるかを決めるのに応動する第１の手段と、該媒体が実質的に磁気的に配向されない３値磁化状態を持つように、該第１の結果が該第３の符号で表わされるかを決めるのに応動する第２の手段とをもつことを特徴とする請求項３５記載の磁気記録装置。

【請求項４７】該第１及び第２の磁化状態が実質的に磁気的に飽和状態であることを特徴とする請求項４６記載の磁気記録装置。

【請求項４８】該第１及び第２の磁化状態が実質的に逆極性であることを特徴とする請求項４７記載の磁気記録装置。

【請求項４９】該第１の手段が該第１及び第２の磁化状態が、決められた時間間隔だけ、該媒体に実質的に同一の大きさで実質的に逆極性の第１、第２の磁界を印加することにより生じさせる手段であり、該第２の該手段が該消磁状態が、決められた時間間隔だけ、該媒体に該第１の磁界を印加し、次いで該第２の磁界を印加することを含む複数回の磁界の反転を印加することにより該消磁状態を起こさせる手段であることを特徴とする請求項４６記載の磁気記録装置。

【請求項５０】該複数回の磁界反転が少なくとも３回の反転を含むことを特徴とする請求項４９記載の磁気記録装置。

【請求項５１】該第１、第２の手段が該第１、第２の記録磁界が、該媒体に近接したコイルにそれぞれ正及び負の電流を流すことにより生じさせるものであることを特徴とする請求項４９記載の磁気記録装置。

【請求項５２】ロジックゲートの配列と、該配列に接続された高周波信号発振器とをもち、該決定手段、該第１の手段、及び該第２の手段が該ロジックゲートの配列に集積化されていることを特徴とする請求項４６記載の磁気記録装置。

【請求項５３】マイクロプロセッサと、該マイクロプロセッサに接続された高周波信号発振器とを含み、該決定手段、該第１の手段及び該第２の手段が該マイクロプロセッサに集積化されていることを特徴とする請求項４６記載の磁気記録装置。

【請求項５４】どの該３値符号が記録されるべきかを決めるための決定手段と、該媒体をそれぞれ第１又は第２の磁気的配向状態を持つように該第１又は該第２の符号が記録されるべきかを決定するのに応動する第１の手段と、該媒体が実質的に磁気的に消磁状態にするように該第３の符号が記録されるべきかを決定するのに応動する第２の手段とをもつことを特徴とする第１、第２、又は第３の符号を記録する磁気記録装置。

【請求項５５】該第１及び第２の磁化状態が実質的に磁気的に飽和状態であることを特徴とする請求項５４記載の磁気記録装置。

【請求項５６】該第１及び第２の磁化状態が実質的に逆極性であることを特徴とする請求項５５記載の磁気記録装置。

【請求項５７】該第１の手段が該第１及び第２の磁化状態が、決められた時間だけ、該媒体に実質的に同一の大きさで実質的に逆極性の第１、第２の磁界を印加することにより生じさせ、該第２の手段が決められた時間間隔だけ、該媒体に該第１の磁界を印加し、次いで該第２の磁界を印加することを含む複数回の磁界の反転を印加することにより該消磁状態を起こさせるための第２の該手段を有することを特徴とする請求項５４記載の磁気記録装置。

【請求項５８】該複数回の磁界反転が少なくとも３回の反転を含むことを特徴とする請求項５７記載の磁気記録装置。

【請求項５９】該第１及び第２の手段が該媒体に近接したコイルに正及び負の電流を流すことによりそれぞれ該第１及び第２の記録磁界を生じさせることを特徴とする請求項５７記載の磁気記録装置。

【請求項６０】マイクロプロセッサと、該マイクロプロセッサに接続された高周波信号発振器とをもち、該決定手段、該第１の手段及び該第２の手段が該マイクロプロセッサに集積されたことを特徴とする請求項５４記載の磁気記録装置。

【請求項６１】ロジックゲートの組合わせと、該組合に接続された高周波信号発振器とをさらにもち、該決定手段、該第１の手段、及び該第２の手段が該ロジックゲートの組合わせに集積化されていることを特徴とする請求項５４記載の磁気記録装置。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明はディジタル磁気記録システム、更に詳しくいえば、ディジタルデータを磁気記憶媒体に記憶する際に３値チャネルを用いる符号化方法及び磁気記録装置に関する。

【０００２】

【従来の技術】情報化時代の到来により、ディジタル情報処理への要求の高まりとともに、ディジタルデータの記憶へ要求も非常に強くなっている。この増大する要求に対応するため、個々の磁気記録装置に記憶される情報の記憶密度を向上させることが必要である。例えば、磁気ディスク装置の容量は過去３０年間に、１０年で１０倍の割合で増強された。この爆発的な増加は、いくつかの要素によりもたらされた。すなわち、マーク　エッチ．クライダーによりプロシーディングス　オブアイイーイーイー　１９８６、１１月号、１４７５～１４７６

頁（Mark H.Kryder, Proceeding of the IEEE, pp. 1475-1476, November 1986.）に発表の“磁気情報記憶技術特集の紹介”における記載のように、ヘッドやディスクの設計上の改良、ディスク媒体における磁性粒子の微細化、ヘッドにおけるギャップ長及び浮上量の狭少化、及びトラック密度向上のための位置決め精度の向上がある。

【０００３】磁気記憶媒体上に正しく記録する際に、“０”、“１”で表わされる２値以上の符号を用いることに関しては、実質的に進歩がなかった。しかしながら、“０”、“１”、“２”の３つの符号が用いられる３値チャネルに符号を記録することにより、記憶容量を増加させる少なくとも４つの試みがなされている。

【０００４】３値磁気記録チャネルを用いて情報を磁気的に記録する第１の手法は、アール．プライス等によりアイイーイーイー　トランザクションズ　オン　マグネティクス、１９７８年、９月、マグ１４巻、５号、３１５～３１７頁(R. Price et al. IEEE Transaction on Magnetics, vol. mag.-14, no.5, pp.315-317, September 1978)に発表された、“実験的、多値、高密度ディスク記憶システム”である。プライス等は磁気記録チャネルを線形化するためにACバイアスを採用し、その磁気記録媒体に３レベルの信号を記録した。線形化の要求により媒体の磁化は飽和よりかなり低いレベルに制限される。すなわち、媒体の一部における全ての磁性粒子がある特定の方向に揃った状態より磁化が低いレベルとなる。その結果、２値チャネルによる飽和記録の方が高いS／N比とある決められたエラー頻度に対しより高い情報密度が達成出来る。

【０００５】３値磁気記録チャネルを用いて情報を磁気的に記録する第２の方法は、ジョージ　ブイ．ヤコビによりアイイーイーイー　トランザクションズ　オン　マグネティクス、１９８１年、１１月、マグ１７巻、６号、３３２６～３３２８頁(Geoge V. Jacoby Transactions on Magnetics, vol. mag.-17, no. pp. 3326-3328, November 1981)に発表された、“３値　３ＰＭ磁気記録符号とシステム”である。ジャコビは、単一パルス、ダブル　パルス、パルス無しの３つの出力波形を生成するような磁化反転を持つ２値飽和記録を用いた。

【０００６】３値磁気記録チャネルを用いて情報を磁気的に記録する第３の方法は、シー．エス．チーとケー．エー．フレイによりアイイーイーイー　トランザクションズン　マグネティクス、１９８２年、１１月、マグ１８巻、６号、１２５９～１２６１頁(C. S. Chi and K. A. Frei IEEE Transactions on Magnetics, vol. mag.-18, no. 6, pp.1259-1261, November 1982.)に発表された、“３値ディジタル記録のための方向性CRA”である。チー等は連続的なAC記録信号を用いた。３値符号は、AC信号に適当な“欠け”を挿入することにより符号化した。AC信号が最大値に達した時の“欠け”は短時間の後、AC信号が回復し、“正”のダブレット　パルスを発生する。同様に、AC信号が最小値の時の“欠け”は“負”のダブレット　パルスを発生し、“欠け”なしは、ダブレットを生じない。ヤコビとチー等により記述されたチャネルは、どちらも２つの磁化反転からなるダブレットを用いる必要がある。ダブレットを形成するには磁化反転は十分離す必要があるため、ダブレットの大きさが記録チャンネルの符号密度を決める。そのため、従来の２値飽和記録技術に比べ正味の利得が無いか、情報密度の点ではあっても極わずかの正味利得しか無い。

【０００７】３値磁気記録チャネルを用いて情報を磁気的に記録する第４の方法は、カテリーヌ　エー．フレンチ等によりアイイーイーイ　トランザクションズ　オン　マグネティクス、１９８７年、９月、マグー２３巻、５号、３６７８～３６８０頁(Catherine A. French et al. IEEE Transactions on Magnetics, vol. mag.-23, no. 5, pp.3678-3680, September 1987.)に発表された”（D、K）制限M次符号を含む結果”である。

【０００８】このチャネルでは、磁化反転の欠けの代わりに、打ち消す様に密に置かれた磁化反転を用い、これにより検出される波形のピークは交互にその極性が変化するという飽和磁気記録の要請を緩和する。この要請の削除により、飽和磁気記録チャネルはピークの有無による２値ではなく、正、負のピーク、ピーク無しの３値となりうる。このチャネルは、チャオによる米国特許USP3,227,454に開示の２値チャネルの拡張とみることが出来る。この方法では、“ゼロ”は偶数の磁化反転で表わされ、“１”は奇数の磁化反転で表わされる。

【０００９】この方法は、チャネルに入力される３値信号の順序に制限一例えば、同じ極性のピークの間には少なくとも一つの“ゼロ”が存在しなければならない一があるため、真の３値チャネルではない。記憶されるデータが記録される情報パターンに依存するため、処理が非線形であり、したがって変調が複雑である。したがって、従来からの２値飽和記録技術に比べ情報密度の点で達成可能な向上は殆どあるいは実質的に無い。

【００１０】情報記憶容量に対する非常に大きな要求に加え、そのような記憶装置に対し、大容量化に対応したエラー発生頻度の低減要求がある。そのため、多くのものの中で、タイミング抽出、非線形低減、エラー訂正に対応可能な符号化の実用化が必要である。

【００１１】情報の符号化には多くの手法があるが、殆どすべての磁気記録媒体では、タイミング抽出と非線形性低減のため“ラン長制限”(RLL)符号を用いている。RLL符号では、連続した２つの磁化反転間隔すなわち磁気記録媒体上の磁化の方向変化の間隔の最大及び最小を制御する。最大間隔が決まっていることにより、検出器内のタイミング抽出機能が頻繁なタイミング信号の更新を受け、信号の喪失を避ける得ることが保証される。磁化反転のような検出可能な信号があるときにのみ更新が行

われるため、そのような信号が頻繁にかつ定期的に現われることが保証される必要がある。高い記録密度では、最小磁化反転間隔により磁化反転が接近しすぎないように保たれる。磁化反転が接近しすぎると、信号振幅が減少するばかりでなく、信号が記録された位置からずれるように干渉を起こす。その結果、タイミング　エラーの確率が増加するような非線形な影響が生じる。

【0012】磁気記録媒体へ記録した情報のエラーの検出、訂正は記録情報に符号化時の冗長性付加により行われている。冗長性を付加するためには、ある量の情報に対して、ある量の信号を付加し媒体に記録することが必要である。媒体上の情報密度の低下を避けるため、信号はより密に記録する必要があり、結果として生のエラー　レートを悪化させる。

【0013】あるエラー　レートに対する情報密度は重要であるが符号化方法により影響を受けるため、コード　レートと表現される密度の指標が開発された。コード　レートは一般的に個々のチャネル信号に対応する平均の情報ビット数で定義される。したがって、２値の“０”、“１”で表わされる２つの信号を持つ２値チャネルは、符号化の冗長性が無い場合にコード　レート＝１となる。符号化は冗長性をもつため、２値符号に対するコード　レートは常に１以下、一般には１／２から３／４の間の値になる。８／９のような高いコード　レートが情報密度に対する冗長性の兼ね合いを取って達成されている。

【0014】それに代わる復号方法では従来からの技術を用いている。“M次チャネル向けの畳み込み符号”と題するカルフォルニア州立大学ロスアンジェルス校における１９７５年の博士論文で、ビー.ディ.トランパス(B.D. Trumpis)は符号化信号がM次符号に拡張された畳み込み符号の応用を研究した。ここでMは２のべき乗の整数である。彼は畳み込み符号を、２値からM次信号へ変換し、これによりコードレート１を保ちながら必要な冗長性を与えた。しかしながら、磁気記録に対して実現可能なM次のチャネル符号は開発されていなかったため、コード　レート１の畳み込み符号の利点はまだ実現されていない。

【0015】

【発明が解決しようとする課題】本発明の目的は、情報が少なくともコード　レート１で符号化され磁気記録媒体に記憶され、飽和磁気記録が用いられ、２値チャネルと同等の磁化反転密度を持ち、線形システムとしてモデル化できるシステムを可能にすることにより、高密度化すなわち大容量化をエラー　レートを確保しながら達成することである。

【0016】

【課題を解決するための手段】上記目的を達成するために、飽和磁気記録による２値チャネルと同程度の磁化反転密度を備えたコード　レート１の符号化システムを実現する。この符号化システムは線形システムでモデル化可能なものである。上記技術を出発点として、システムは３値チャネルを備え、記録される情報の冗長性を確保するため畳み込み符号化が用いられる。

【0017】好ましい実施例では、本発明システムは、第１又は第２の２値符号を表わすビット列を符号化する。個々の項が第１、第２、第３の数値を持つインパルス応答ベクトルが用いられる。上記ビット列は上記ベクトルと畳み込まれ、その値を３で割算した値を発生し、第１、第２、第３の３値符号で表される剰余を発生する。

【0018】また、本発明システムは、上記第１、第２、第３の３値符号を磁気記録媒体上に記録する。第１、第２の３値符号は、それぞれ磁気記録媒体を第１、第２の磁化の状態に対応することによって記録される。第３の符号は、上記記録媒体が実質的に消磁状態になるようにすることによって記録される。

【0019】本発明システムは、更に、上記記録媒体に記録された情報を再生する部分を持つ。上記３値符号は、検出され（さらに等化され）たパルスとして読み出され、その後３値信号から元の２値符号の列に復号される。

【0020】

【作用】本発明では、飽和記録を用いたため、与えられたエラー発生頻度において、従来の２値記録で達成可能なものと同程度の高いS/N比と情報密度が得られる。ダブレットを許容するようなチャネル符号間の間隔をとる必要が無いため、それにより情報格納密度が向上可能である。更に、本発明は線形システムとしてモデル化可能できることから、非線形チャネルに対する等化技術より簡単で低コストな線形等化器を用いることが可能である。さらにまた、符号化アルファベットの絶対最小展開を保証しつつ、コードレート１の畳み込み符号を用いることが可能である。また、コードレート１の符号を用いたため、２値－３値符号器と３値－２値復号器への入力からの出力される情報は同一コードレートであり、そのためタイミングの制御が簡素化される。

【0021】

【実施例】以下実施例で詳細に説明を行う。

【0022】図１に、本発明の磁気記録システム１０を示す。このシステムは、２値信号を磁気記録媒体に記録、再生するために、２値から３値への畳み込み符号と３値の磁気記録チャネルを用いる。

【0023】図１において、信号線１２の２値信号（すなわちビット列）は符号器１４に入力され、そこで畳み込み符号を用い、上記２値信号は３値信号に変換される。３値信号１３は、線１６で示されるように、符号器１４から記録ロジック部１８に出力される。記録ロジック部１８は、上記３値信号に対応して正、負又は交流の電流信号を発生する。上記電流信号は、線２０で示され

るように、記録ロジック部１８から周知の記録増幅器２２に出力される。記録増幅器２２は上記電流を増幅し、線２４で示すように、周知の記録ヘッド２６に出力する。記録ヘッド２６は情報記憶に用いられる周知のディジタル磁気記録媒体２８に上記電流信号を記録する。媒体２８に記憶された信号は再生ヘッド３０で再生され、再生ヘッド３０は、線３２で示すように、電圧出力を前置増幅器３４に出力する。前置増幅器３４はその電圧信号を増幅し、増幅された出力を線３６で示すように、検出器３８に出力する。検出器３８はその増幅された電圧信号を３値信号に変換し、３値信号を線４０で示すように、復号器４２に出力する。復号器４２はその３値信号を２値信号に変換し、線４４に２値信号を出力する。

【００２４】図２及び図３（ａ）、（ｂ）、（ｃ）は、拘束長（K）が７の２値から３値への畳み込み符号器１４の構成要素を示す。図２において、符号器１４はシフトレジスタ２００、パス、シフト、ゼロ（PSZ）要素２０２の集合とモジュロ３の２値加算器２０４をもつ。加算器２０４はマイクロプロセッサであってもよい。レジスタ２００は７つのビットを記憶するための７つのセル２００a～２００gを含み、タイムクロック発生器（図示せず）により発生されたクロックパルス信号により駆動される。各クロックパルスが来る度に、セル２００aから２００gに格納されたビットは、セル２００bから２００gに１セルだけシフトされ、信号線１２の新しいビットが入力されセル２００ａに記憶されるとともに、以前にセル２００gに記憶されていたビットは消失する。PSZの集合２０２は７つの要素２０２aから２０２gを含み、セル２００aから２００gの内容のコピーが並列にそれら要素を通過する。

【００２５】図３（ａ）、（ｂ）、（ｃ）において、要素２０２aから２０２gのそれぞれはパス、シフト及びゼロモードで個々に動作するようプログラム化可能である。要素２０２a から２０２g がパスモード（図３（ａ））の場合は、対応するセル２０２a-２０２gからコピーされたビット“１”又は“０”は“パス”し、各々００又は０１が加算器２０４に入力される。それに対し、要素２０２ａ－２０２ｇがシフトモード（図３（ｂ））の場合には、対応するセル２０２ａ－２０２ｇからコピーされたビット“０”又は“１”はシフトされ、各々００又は１０が加算器２０４に入力される。要素２０２ａ－２０２ｇがゼロモード（図３（ｃ））の場合には、セル２０２ａ－２０２ｇに対応するビットが“０”又は“１”であるのに無関係に００が加算器２０４に入力される。

【００２６】システム１０においてエラーを最小にする最適入力ベクトルは１０進法で[１、１、１、２、０、２、２]である。図２を参照し、このベクトルはPSZ要素２０２aから２０２gをそれぞれパス、パス、パス、シフト、ゼロ、シフト、シフトにすることにより実行できる。レジスタ２００のそれぞれのシフトにより、加算器２０４はPSZ要素２０２ａ－２０２ｇからの入力の和を求め、その和を３で割り、剰余（２値の００、０１、１０）を出力線１６a、１６bに出力する。PSZ要素２０２aから２０２gはこのようにして３値インパルス応答ベクトルを保存するように動作し、加算器２０４は３値インパルス応答ベクトルとレジスタ２００の２値の内容を畳み込む働きをする。その結果として、入力信号線１２の２値入力信号は２ビットの対（３つの符号に対応する）の列で構成される３値信号に変換され、出力線１６a、１６bに出力される。

【００２７】図４は記録ロジック部１８のロジック動作を示したものであり、ロジック部は周知の高周波発振器４００、アンドゲート４０２、オアゲート４０４及び周知の電圧増幅器とバイアス発生器４０６をもつ。発振器４００は望ましくはシステムのクロックレートの４から６倍の周波数で発振する信号を発生する。ANDゲート４０２は、発振器４００の出力、信号線１６ａ、１６ｂの反転信号の論理積をとる。ORゲート４０４はANDゲート４０２の出力と信号線１６aの信号の論理和をとる。このようにして、信号線１６a、１６bの信号が２値信号で００、０１、１０であると、ORゲート４０４の出力信号はそれぞれに対応し発振信号、ロー信号、ハイ信号になる。ORゲート４０４の出力信号は部品４０６に入力され、そこで信号を増幅及びバイアスし、ハイ及びロー信号はそれぞれ＋１と－１で表わされるような同一振幅であるが逆極性のものになる。部品４０６で発生される電圧信号は信号線２０を介して記録増幅器２２に出力される。

【００２８】記録増幅器２２は信号線２０の信号を記録ヘッド２６が磁気記録媒体２８に信号を記録するのに十分な大きさに増幅する。増幅器２２とヘッド２６は磁気記録システム、特にディジタル磁気記録システムで広く使われ、よく知られている増幅器及びヘッドのいずれでもよい。ハイ（＋１）又はロー（－１）信号が記録ヘッド２６に入力されたときには、周知の飽和記録が用いられ、それにより磁界が媒体２８の一部の特定領域で粒子の実質的にすべて磁化を、二つの相反する方向の磁化状態（極性）のうちの一つに揃うように印加される。ゼロ（発振）信号が記録ヘッド２６に入力されたときには、振動的な磁界が媒体２８の特定の部分領域での粒子の磁化がランダムに配向するよう印加され、その結果全体としては磁化の無い状態になる。すなわち媒体２８の部分領域でハイ又はロー信号が振動的な信号により消去される。これは、従来のチャネルの磁化反転による記録に対し、チャネルの状態を用いた情報の記録であると言える。

【００２９】磁気記録媒体２８への情報の記録の後、その情報は周知の再生ヘッド３０と前置増幅器３４により再生される。両者とも良く知られた技術であり、広く利

用可能である。再生ヘッド３０は媒体２８上の磁化に対応した電圧信号を発生する。前置増幅器３４は再生ヘッド３０で再生された電圧出力を適切な振幅まで増幅し、信号線３６に信号を出力する。

【００３０】図６に、チャネル状態列（＋１、０、＋１、０、－１、＋１、＋１、－１、０、＋１）に対応する記録ヘッド２６により媒体に記録される電流波形６００を示す。再生ヘッド３０により読み出される、記録電流に対応した電圧波形６０２（チャネル状態の不完全微分に相当する）を記録電流波形６００とあわせて示す。

【００３１】マイクロプロセッサ（図示せず）を用いても可能な検出器３８は、信号線３６の電圧信号を受信し、望ましくは周知の符号ごとの判定帰還型等化器（DFE）手法を用い等化する。DFEを用いることにより、その電圧信号はサンプリングされ、符号間干渉（ISI、隣接符号による特定符号への影響）が取り除かれる。その結果、実質的に理想的なサンプル値列が出力され、等化された３値符号が検出器３８から信号線４０に出力される。ここで述べられたDFE技術は良く知られているものであり、広く活用可能な技術である。信号線４０の３値符号は、信号線１６の符号と同様に、ビット対（２値符号）００、０１及び１０で表わされる。

【００３２】検出器３８からの３値符号は復号器４２により２値符号に復号される。復号器４２は周知のビタビ手法（又はその縮退型のもの）を用いることが望ましい。信号線１２に入力される２値符号列と本質的に同じものである２値符号列が信号線４４に出力される。復号器４２はマイクロプロセッサ（図示せず）を用いることも可能である。

【００３３】本発明は多くの形式と具体例が可能である。ここで示された具体例は、発明を制限するよりも説明するためのものであり、発明の精神や範囲から逸脱することなく変形することが可能である。例えば、図２に示した符号器１４を例にとると、シフトレジスタ２００はランダムアクセスメモリ（RAM）の様な他の形式の記憶素子に置き換え可能である。

【００３４】別の実施例としては、ＰＳＺ素子２００aから２００gが既知で固定されている場合には、PSZ素子及び加算器２０４は図５に示す例として示したロジック回路で置き換え可能である。さらに、好ましい実施例に記述のベース３のインパルス応答ベクトルは他のベース数の、例えばベース４のインパルス応答ベクトルで置き換えることか可能である。

【００３５】さらに別の実施例として、畳み込み符号器１４は好ましい実施例における拘束長K＝７の長さより大きい、または、小さい拘束長Kを用いたものでも実施可能である。最小エラーに最適化されたインパルス応答ベクトルは図７に示す計算器プログラムを用いて、拘束長Kに対し求めることが可能である。そのようなプログラムは、モデル化した符号器に１で始まりK個のゼロで終わる長さ２値列を２＊Kの起こりうるすべての２値列をモデル化された符号器を通して流し、最小エラーを計測することにより、すべての３のK乗個のベクトルをテストする。最小エラーのうち、最大となるベクトルが最適ベクトルである。

【００３６】さらに別の実施例として、符号は状態そのものの代わりにチャネル状態間の変化を用いて媒体上に記録することも可能である。検出器３８に用いられたDFE手法は、磁気記録媒体に記録された符号列を再生するために他の符号ごとの方式、例えば良く知られたパーシャルレスポンス方式又はピーク検出方式で起きかえることも可能である。ピーク検出方式が用いられた場合には、３値符号列をその磁化反転が元の符号列に含まれた情報を表す他の３値列に変換又はプリコードするために、他の符号器が必要である。ビタビ検出器（又はその縮退型の）のような最尤復号器を用いることにより、検出器３８と復号器４２は符号の代わりに磁気記録媒体に記録された、一連のつながりを検出、復号する一つの部品にしてもよい。さらに別の実施例として、他の数のベースを含む、他の形のデータあるいは情報が信号線１２に入力されてもよい。

【００３７】発明に関する実施例を示し、説明を加えたが、広い範囲の修正、変更及び挿入が前述の開示に対しあるいは本発明のある特質が、他の特質の対応した使い方をせずに採用される場合が起こりうる。したがって、付記された請求項は広くかつ発明の範囲と一致するように解釈されるべきである。

【００３８】

【発明の効果】本発明は従来技術に対し多くの利点を持つ。第１の利点は、飽和記録を用いたため、与えられたエラー発生頻度において、高いS／N比と従来からの２値記録で達成可能な情報密度と同程度の情報密度が得られる。第２の利点は、ダブレットを許容するようなチャネル符号間の間隔をとる必要が無いため、それにより情報記憶密度が向上可能な点である。第３の利点は本発明は線形システムとしてモデル化可能できることから、非線形チャネルに対する等化技術より簡単で低コストな線形等化器が用いることが可能な点である。第４の利点は、符号化アルファベットの絶対最小展開を保証しつつ、コードレート１の畳み込み符号を用いることが可能な点である。第５の利点は、コードレート１の符号を用いたため、２値－３値符号器と３値－２値復号器への入力からの出力される情報は同一コードレートであり、そのためタイミングの制御が簡素化可能である点である。

【図面の簡単な説明】

【図１】本発明による３値磁気記録再生システムの一実施例の機能ブロック図

【図２】図１の２値－３値符号器の機能ブロック図

【図３】図２の（PSZ）要素２０２の概念的な構成図

【図４】図１の記録ロジック部１８の機能ブロック図

【図5】図1の符号器14の他の実施例のロジック回路図

【図6】図1における磁気記録媒体へ記録する電流波形及びそれに対応する出力電圧信号の波形図

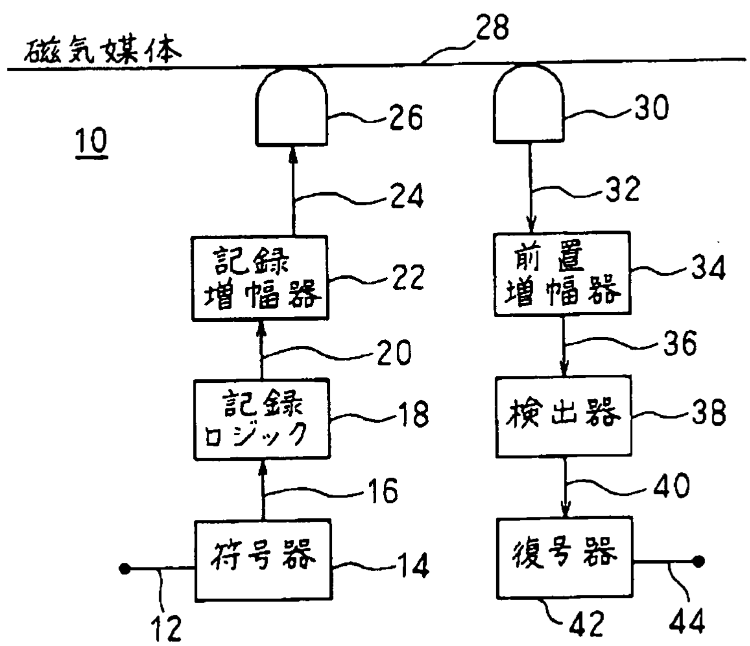
【図7】図2に示す符号器を開発するさいに使用された計算機プログラム用のソースコードを示す図

【符号の説明】

1 0……磁気記録システム
1 4……符号器器
1 8……記録ロジック
2 2……記録増幅器
2 6……記録ヘッド
2 8……磁気記録媒体
3 0……再生ヘッド
3 4……前置増幅器
3 8……検出器
4 2……復号器

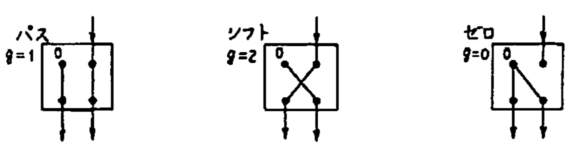
【図1】

図1



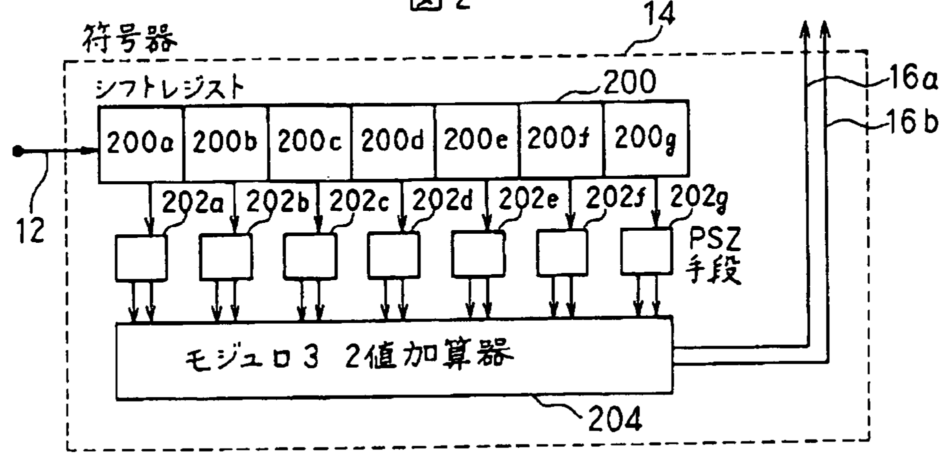
【図3】

図3



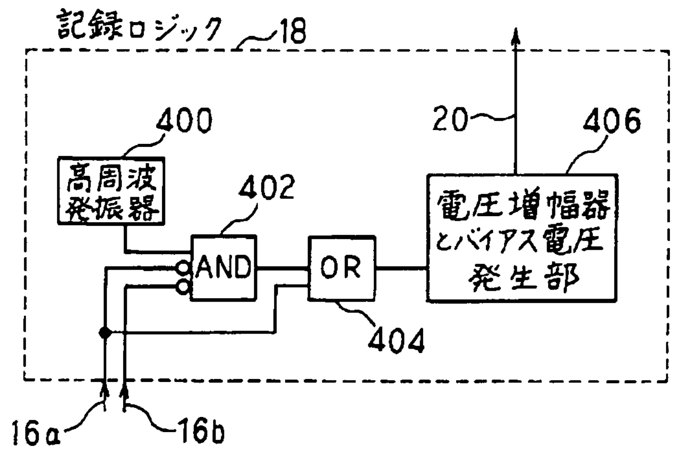
【図2】

図2


符号器
14
シフトレジスト
200
200a
200b
200c
200d
200e
200f
200g
16a
16b
12
202a
202b
202c
202d
202e
202f
202g
PSZ
手段
モジュロ3 2値加算器
204

【図4】

図4


記録ロジック
18
400
高周波
発振器
402
AND
OR
404
20
406
電圧増幅器
とバイアス電圧
発生部
16a
16b

【図6】

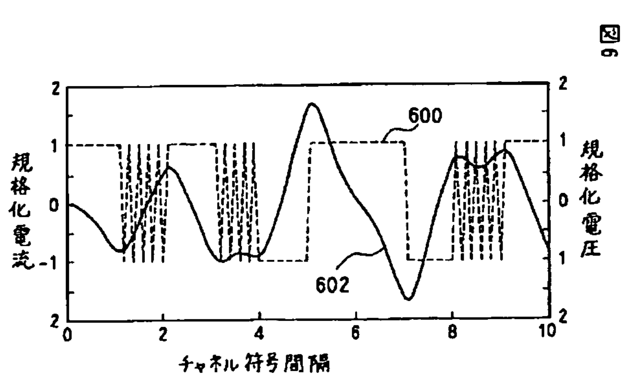
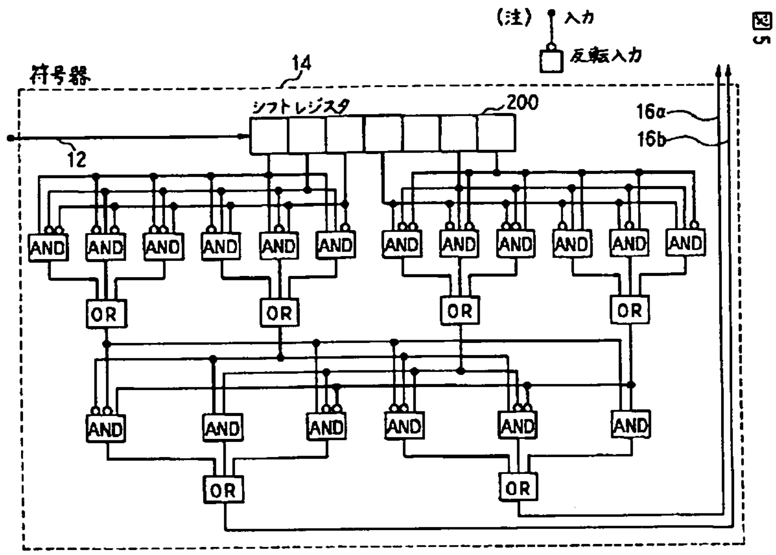


図6
600
602
規格化電流
規格化電圧
チャネル符号間隔

【図5】



【図7】

図7

```
%This is a MATLAB program that performs an exhaustive search to
%find the optimum binary-to-ternary convolutional code for a
%given constraint length.

k=input('Desired code constraint length:');

%generate matrix I whose rows provide all necessary test inputs
tmp1=[1:2^(k-2)]'-1;
I(:,1)=ones(length(tmp1),1);
for p=(k-1):-1:1
  tmp2=rem(tmp1,2^(p-1);
  I(;,p+1)=(tmp1-tmp2)/2^(p-1);
  tmp1=tmp2;
end
I(:,k+1:2*k)=zeros(length(tmp1),k);
%generate matrix G whose rows provide all possible code vectors
tmp1=[1:3^k]'-1;
for p=k:-1:1
  tmp2=rem(tmp1,3^(p-1);
  G(:,p)=(tmp1-tmp2)/3^(p-1);
  tmp1=tmp2;
end
%find the minimum dist. for each code,and const # shortest paths
dmin=ones(3^k,1)*999
nmin=zeros(3^k,1);
for inp=1:2^(k-1)
  ham=zeros(3^k,1);
  for n=1:2*k)
    sm=zeros(3^k,1);
    for p=1;min(n,k)
      sm=sm+G(:,p)*I(inp,n-p+1);
    end
    ham=han+(rem(sm,3)-=0);
end
nmin=(ham<=dmin)+(nmin,*(ham>=dmin));
dmin=(ham.*(ham<=dmin)+(dmin.*(ham>dmin));
end
dminnmax=man(dmin);
opt=find(dmin==dminmax);
nminmin=min(nmin(opt));
opt=find((dmin==dminmax)&(nmin==nminmin));
%print results of search
disp(['The best codes of constraint length', num2str(k),'are:'])
disp(G(opt,:))
disp('The hamming distance of these codes is:')
disp(dminmax)
disp('The number of paths at this distansis:')
disp(nminmin)
```

フロントページの続き

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